

Hospital Discharge Diagnosis Position: Impact on Adult Pneumonia Burden Estimates

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The burden of US adult hospitalizations for pneumonia is substantial. Many studies have used administrative claims data to determine the number of these hospitalizations, with annual estimates of 1200 to 2000 pneumonia hospitalizations per 100,000 persons 65 years and older and more than 4000 per 100,000 among those 85 years and older.^{1,3} Evaluating hospital discharge administrative data is critical in assessing the public health impact of disease prevention strategies, particularly against pneumococcal disease.^{1,2} Nevertheless, most studies using administrative data are limited to pneumonia coded as the primary diagnosis (first diagnosis field [DF] of hospital discharge) or extend the definition only to septicemia or respiratory failure coded as the primary diagnosis with pneumonia coded as the secondary or higher DF.¹⁻⁶ Thus, patients with pneumonia in the second or higher discharge DF are generally excluded from pneumonia burden estimates, but the impact of this practice on estimates is not well researched.

Coding practices vary based on several considerations (eg, administrative considerations, billing, training, experience, local practice), affecting the assigned position of pneumonia discharge DFs. Notably, studies using administrative databases can find different incidence rates (IRs) depending on which discharge DF positions are included; other outcomes may also be affected.^{6,7} For example, CMS uses only primary diagnoses when estimating hospital 30-day risk-standardized mortality rates associated with pneumonia and reimburses hospitals according to those rates.^{7,8} Patients with pneumonia can also present with sepsis or respiratory failure, which are increasingly used as primary diagnoses.^{6,7} Presumably these patients have higher mortality risk, so their exclusion may falsely lower pneumonia mortality. Using nationally representative databases, we assessed overall IRs of pneumonia hospitalization and effects of different discharge DFs for pneumonia coding.

METHODS

Study Design and Data Sources

Pneumonia hospitalizations and corresponding hospital length of stay (LOS); direct medical costs; hospital discharge disposition,

ABSTRACT

OBJECTIVES: Pneumonia hospitalization studies using administrative claims rely on pneumonia coded in the first discharge diagnosis field over pneumonia in any coded field, and few have evaluated disposition following discharge. This study reports the total disease burden and discharge disposition among patients with pneumonia coded in any diagnosis field.

STUDY DESIGN: Retrospective database review.

METHODS: Data from the 2014 National Inpatient Sample of the Healthcare Cost and Utilization Project, a population-weighted, 20% sample of all US community hospitalizations, were analyzed for all pneumonia hospitalizations in adults aged 18 to 64 years and 65 years or older. Number of hospitalizations, hospital stay length, direct medical costs, in-hospital mortality, patient discharge disposition, illness severity, and likelihood of dying were evaluated based on the diagnosis field of pneumonia as a discharge diagnosis (eg, first, second, third, or further).

RESULTS: In 2014, an estimated 2.4 million US adult hospitalizations were associated with pneumonia in any of the discharge diagnosis positions (33%-35% in first, 33%-36% in second, and 29%-34% in further positions). When estimates were based only on hospitalizations with pneumonia in the first diagnosis field, approximately 66% of hospitalizations, 78% of hospital days, 87% of in-hospital deaths, 76% and 73% of transfers to short-term hospitals and skilled nursing facilities, 68% of discharges with home health care services, and 82% of direct medical costs were excluded.

CONCLUSIONS: Pneumonia hospitalizations were associated with substantial health care resource utilization and in-hospital mortality. Relying only on pneumonia in the first hospital diagnosis field may potentially underestimate the burden associated with pneumonia hospitalizations.

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TAKEAWAY POINTS

Commonly estimated pneumonia burden among US adults is based primarily on hospitalizations with pneumonia in the first discharge diagnosis field. This study generated estimates including hospitalizations with pneumonia in any diagnosis field.

- ▶ There is substantial health care resource utilization and in-hospital mortality associated with pneumonia hospitalizations.
- ▶ Estimates of disease burden were lower when relying solely on pneumonia in the first hospital diagnosis field vs including pneumonia coded in any diagnosis field.
- ▶ For more sensitive estimates of incidence rates and disease burden, all appropriate hospitalizations, regardless of the discharge diagnosis field in which pneumonia is coded, may be used.

FIGURE 1. Identification and Classification of Pneumonia-Related Hospitalizations

1. Identification of pneumonia-related hospitalization

Based on any of the following *ICD-9-CM* codes being in any of the up to 30 diagnosis fields in the hospital discharge form:

- 480.xx Viral pneumonia
- 481.xx Pneumococcal pneumonia (*Streptococcus pneumoniae* pneumonia)
- 482.xx Other bacterial pneumonia
- 483.xx Pneumonia due to other specified organism
- 484.xx Pneumonia in infectious diseases classified elsewhere
- 485.xx Bronchopneumonia, organism unspecified
- 486.xx Pneumonia, organism unspecified
or
- 487.0 Influenza with pneumonia

2. Classification of pneumonia-related hospitalization

Based on location of first *ICD-9-CM* code for pneumonia across the discharge diagnosis fields:

- A. Pneumonia in first diagnosis field
- B. Pneumonia in second diagnosis field
- C. Pneumonia in any other diagnosis field

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

including in-hospital case fatality rate (CFR); illness severity; and mortality risk were estimated using National Inpatient Sample (NIS) data (described in the [eAppendix](#) [available at [ajmc.com](#)]⁹⁻¹¹). Data from 2014 were analyzed, as the *International Classification of Diseases* codes changed from the *Ninth Revision, Clinical Modification (ICD-9-CM)* to the *Tenth Revision, Clinical Modification (ICD-10-CM)* in September 2015. US Census Bureau population projections were used for age-group population estimates using July 2014 projected population estimates.¹²

Identification of Pneumonia Hospitalizations

For the purposes of this study, a pneumonia-associated hospitalization was defined as any hospitalization with a pneumonia diagnosis *ICD-9-CM* code (480.xx-486.xx or 487.0) in any discharge DF; codes were selected based on previously published research.¹ Each hospitalization in the NIS database contained 30 or fewer discharge DFs. Because NIS has a complex sample design (oversampling, uneven selection probabilities, nonresponses), nationally

representative estimates were generated using Healthcare Cost and Utilization Project (HCUP) variance calculations and sample weights.¹⁰ The criteria used for identification and classification of pneumonia-related hospitalizations are summarized in [Figure 1](#).

Outcomes and Data Analysis

Age-specific IRs for the overall US population were calculated as hospitalizations per 100,000 persons per year. Age group-specific estimates were obtained by dividing the number of all pneumonia hospitalizations by the US Census population estimates for 2014 (199,030,227 and 46,243,211 adults aged 18-64 years and ≥65 years, respectively; hereafter, they are referred to as younger and older adults).

IRs and frequency distributions of pneumonia hospitalizations were analyzed by diagnostic position in which pneumonia was first coded. Because of similar frequency distribution, all outcomes of interest were grouped by whether the pneumonia diagnosis code occurred in the first, second, or any further discharge DF. Hospital LOS, direct medical costs, hospital discharge disposition, illness severity, and mortality risk were described similarly.

HCUP provides information on charges for each hospitalization and cost to charge ratios.¹¹ Hospitalization charges were converted into hospitalization costs using HCUP cost to charge ratio. Direct medical costs of pneumonia hospitalization were initially estimated in 2014 US\$ and converted to 2018 US\$ using the Consumer Price Index of medical care increase over this time (11.3%).¹³ Mean values per hospitalization and cumulative totals were calculated for hospital LOS and costs.

Patient hospital discharge disposition was assessed and described with frequency distributions. A patient could have died in the hospital (in-hospital CFR); been transferred to a short-term care facility, skilled-nursing facility (SNF), or intermediate-care facility (ICF); been discharged with home health care; received routine discharge; been discharged against medical advice; or been discharged (alive) with undefined destination.¹⁰

Several analyses were performed to characterize the conditions associated with pneumonia across different discharge DFs. First, the top 10 *ICD-9-CM* codes occurring in the first DF when pneumonia occurred in the second or any other DF were assessed. Further analyses were used to determine the most common *ICD-9-CM* codes within the first 5 discharge DFs and All Patient Refined Diagnosis-Related

Groups (APR-DRGs) associated with pneumonia hospitalizations in the first, second, or any other discharge DFs; most common ICD-9-CM codes and APR-DRGs were predefined as those occurring in at least 1% of all pneumonia hospitalizations. Lastly, we evaluated the prevalence of ventilator-associated hospital-acquired pneumonia (VAP; ICD-9-CM code 99731) and pneumonitis due to inhalation of food or vomitus (aspiration pneumonia; ICD-9-CM code 5070) occurring with pneumonia in the first, second, or any other discharge DF.

Each HCUP hospitalization included information on overall illness severity (ie, loss of function and mortality risk levels) using a 3M proprietary classification-independent system, which considers presence and seriousness of underlying comorbidities.¹⁴ Frequency distribution of illness severity and likelihood of dying were calculated using pneumonia discharge DF positions.

Comparing Alternative Criteria for Identifying Pneumonia-Associated Hospitalizations

We compared our approach for classifying any pneumonia-associated hospitalization with that followed by Griffin and colleagues.¹ Both studies used the same ICD-9-CM codes for pneumonia. Our study included any hospitalization with a pneumonia code in any discharge DF as a proxy for a pneumonia-associated hospitalization. Griffin and colleagues¹ identified pneumonia hospitalizations as those with pneumonia coded in the first DF or pneumonia coded in any field if septicemia, meningitis, or empyema was the primary diagnosis.

Analyses were performed using SAS software version 9.4 (SAS Institute). Ethical conduct within the study is summarized in the eAppendix.

RESULTS

Pneumonia Hospitalizations

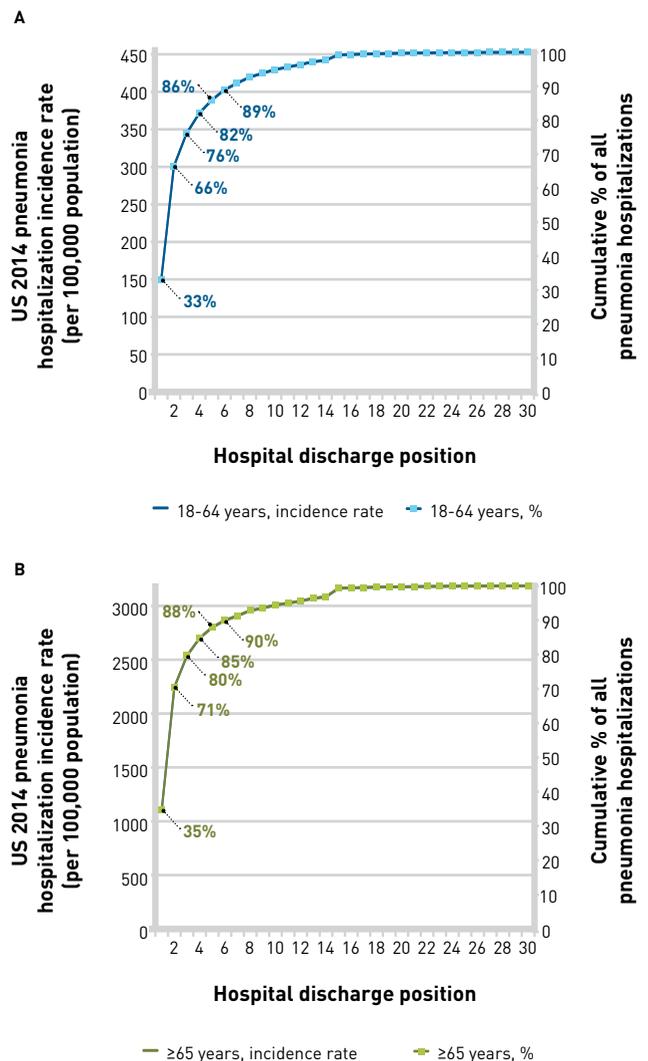
In 2014, approximately 2.4 million acute hospitalizations of US adults included pneumonia diagnosis at discharge. Of these, 38% (~900,000 hospitalizations) and 62% (~1.5 million hospitalizations) occurred in younger and older adults, respectively. Annual overall pneumonia hospitalization incidences in younger and older adults were 453 and 3185 per 100,000 persons, respectively (Figure 2).

Among all possible hospital discharge diagnoses, pneumonia was within the first 6 DFs in 90% of all pneumonia hospitalizations (Figure 2). Pneumonia was coded in the first or second DF position in approximately one-third each of all pneumonia hospitalizations (Table 1). Overall, 34% of younger adults and 29% of older adults had a pneumonia diagnosis in any further discharge DF (ie, beyond second position).

LOS and Costs

The mean LOS of all hospitalizations with pneumonia included in any discharge DF was 8.4 and 7.3 days in younger and older adults, respectively (Table 1). Pneumonia hospitalizations were associated with approximately 18.3 million hospital days, 41.5% of which occurred among younger adults and 58.5% of which occurred among

FIGURE 2. Annual Incidence and Cumulative Frequency of Pneumonia Hospitalizations by Diagnosis Across Hospital Discharge Fields in (A) Adults Aged 18–64 Years and (B) Adults Aged ≥ 65 Years



older adults. The lowest mean LOS and the lowest number of total hospital days were observed when pneumonia was in the first DF.

Mean direct medical costs of all hospitalizations with pneumonia included in any discharge DF (2018 US\$) were \$24,637 in younger adults and \$18,360 in older adults (Table 1). The estimated cost associated with pneumonia hospitalizations in 2014 was \$48.3 billion (2018 US\$); 45% of these costs were attributable to younger adults and 55% to older adults. Among younger adults, 15%, 25%, and 60% of total costs were attributable to patients with pneumonia in the first, second, or any other discharge DF, respectively, vs 21%, 31%, and 49% for older adults. The available data were not sufficient to determine the relative contributions of pneumonia

TABLE 1. Pneumonia Hospitalizations, Hospital Days of Stay, and Direct Medical Costs by Discharge DF*

Study population	Hospitalizations		Number of hospital days of stay			Direct medical costs		
	Estimate (SE)	%	Mean stay Estimate (SE)	Cumulative days Estimate (SE)	%	Average cost Estimate (SE)	Cumulative costs Estimate (SE)	%
Aged 18-64 years								
Pneumonia in first DF	297,975 (3105)	33	4.9 (0.0)	1,448,031 (18,105)	19	\$11,341 (\$113)	\$3.3 billion (\$0.0 billion)	15
Pneumonia in second DF	301,100 (4056)	33	7.0 (0.1)	2,114,780 (35,923)	28	\$18,147 (\$269)	\$5.4 billion (\$0.1 billion)	25
Pneumonia in any other DF	302,395 (4804)	34	13.3 (0.2)	4,014,771 (86,981)	53	\$44,493 (\$848)	\$13.1 billion (\$0.4 billion)	60
All pneumonia hospitalizations	901,470 (9730)	100	8.4 (0.1)	7,577,582 (120,510)	100	\$24,637 (\$398)	\$21.8 billion (\$0.5 billion)	100
Aged ≥ 65 years								
Pneumonia in first DF	510,190 (5323)	35	5.2 (0.0)	2,641,791 (31,845)	25	\$10,886 (\$76)	\$5.5 billion (\$0.1 billion)	21
Pneumonia in second DF	527,545 (6907)	36	6.8 (0.0)	3,562,436 (50,393)	33	\$15,550 (\$132)	\$8.1 billion (\$0.1 billion)	31
Pneumonia in any other DF	433,825 (6037)	29	10.3 (0.1)	4,485,271 (66,383)	42	\$30,870 (\$399)	\$12.9 billion (\$0.2 billion)	49
All pneumonia hospitalizations	1,471,560 (14,999)	100	7.3 (0.0)	10,689,499 (123,018)	100	\$18,360 (\$174)	\$26.5 billion (\$0.4 billion)	100

DF, diagnosis field; SE, standard error.

*Costs are reported in 2018 US\$.

vs other associated conditions to either LOS, total hospital days, or direct medical costs.

Patient Disposition After Hospitalization

Mean in-hospital CFRs of all pneumonia hospitalizations were 5.7% among younger adults and 8.9% among older adults (Table 2). There were 182,730 pneumonia-associated in-hospital deaths in younger (28.1%) and older (71.9%) adults (Table 2). Of in-hospital deaths in younger adults, 9%, 19%, and 72% had pneumonia in the first, second, or any other discharge DF, respectively, vs 15%, 28%, and 57% in older adults.

Hospital discharge disposition after pneumonia hospitalization among younger and older adults included transfers to another short-term hospital (3.7% and 3.0%, respectively) or SNF/ICF (15.1% and 34.9%), and discharge as routine (61.0% and 33.7%) or to home with home health care services (12.2% and 18.9%) (Table 2). Few patients were discharged against medical advice. As with other outcomes, the percentage of transfers was lowest when the pneumonia diagnosis was primary (Table 2).

ICD-9-CM Codes and APR-DRGs Associated With Pneumonia Hospitalizations

Septicemia was the most common condition noted in the first DF for hospitalizations associated with pneumonia in the second DF (24.2%) or any other DF (28.2%) (eAppendix Table 1). Eight of the 10 most common conditions noted in the first DF (including septicemia, chronic obstructive pulmonary disease, congestive heart

failure, and respiratory failure) were similarly prevalent regardless of whether pneumonia was listed in the second DF or any other DF.

The 5 most common nonpneumonia conditions associated with pneumonia listed in any DF (excluding hypertension) were respiratory failure, septicemia, acute renal failure, exacerbation of obstructive pulmonary disease, and acute and chronic respiratory failure/congestive heart failure (both occurring with approximately the same frequency) (eAppendix Table 2). At least 1 of these conditions was reported along with 51.7% of hospitalizations with pneumonia listed in the first DF, 86.4% of hospitalizations with pneumonia listed in the second DF, and 99.9% of hospitalizations with pneumonia listed in any other DF.

Three APR-DRGs (all defined as “simple pneumonia”) accounted for 87.6% of all hospitalizations associated with pneumonia listed in the first DF (including 39.4% with complicating or comorbid conditions, 30% with major complicating or comorbid conditions, and 18.2% without complicating or comorbid conditions) (eAppendix Table 3). In contrast, these 3 APR-DRGs were very rarely associated with pneumonia listed in the second or any other DF; rather, septicemia was most commonly associated with pneumonia in the second DF (27.0%) or in any other DF (30.9%). VAP and aspiration pneumonia were associated with 0.2% and 1.2% of all pneumonia hospitalizations, respectively (eAppendix Table 4).

Severity and Likelihood of Dying

In both age groups, the percentage of patients with major to extreme illness increased with pneumonia discharge diagnosis position,

TABLE 2. Disposition of Pneumonia Hospitalizations by Discharge DF

	In-hospital deaths Estimate (SE)	Transfer to short-term hospital Estimate (SE)	Transfer to SNF, intermediate care or other facility Estimate (SE)	Routine discharge Estimate (SE)	Home health care Estimate (SE)	Discharge against medical advice Estimate (SE)	Discharged alive, destination unknown Estimate (SE)
Frequency distribution (row percentages), %							
Aged 18-64 years							
Pneumonia in first DF	1.5 (0.1)	2.6 (0.1)	8.2 (0.1)	76.1 (0.2)	9.1 (0.2)	2.5 (0.1)	0.0 (0.0)
Pneumonia in second DF	3.2 (0.1)	3.7 (0.1)	12.4 (0.2)	65.6 (0.3)	12.8 (0.2)	2.2 (0.1)	0.0 (0.0)
Pneumonia in any other DF	12.2 (0.2)	4.9 (0.1)	24.5 (0.3)	41.7 (0.3)	14.7 (0.2)	1.8 (0.1)	0.1 (0.0)
All pneumonia hospitalizations	5.7 (0.1)	3.7 (0.1)	15.1 (0.1)	61.0 (0.2)	12.2 (0.2)	2.2 (0.0)	0.1 (0.0)
Aged ≥ 65 years							
Pneumonia in first DF	3.9 (0.1)	2.1 (0.1)	29.8 (0.2)	44.5 (0.2)	19.1 (0.2)	0.4 (0.0)	0.1 (0.0)
Pneumonia in second DF	6.9 (0.1)	3.1 (0.1)	34.8 (0.2)	34.5 (0.2)	20.3 (0.2)	0.3 (0.0)	0.1 (0.0)
Pneumonia in any other DF	17.2 (0.2)	4.0 (0.1)	41.1 (0.3)	20.1 (0.2)	17.1 (0.2)	0.3 (0.0)	0.2 (0.0)
All pneumonia hospitalizations	8.9 (0.1)	3.0 (0.1)	34.9 (0.2)	33.7 (0.2)	18.9 (0.2)	0.4 (0.0)	0.1 (0.0)
Number of hospitalizations							
Aged 18-64 years							
Pneumonia in first DF	4550 (166)	7725 (223)	24,305 (477)	226,660 (2446)	27,155 (564)	7360 (236)	45 (15)
Pneumonia in second DF	9760 (282)	11,195 (285)	37,375 (692)	197,325 (2776)	38,575 (865)	6650 (222)	65 (19)
Pneumonia in any other DF	37,025 (854)	14,770 (389)	74,005 (1424)	126,035 (2194)	44,455 (1062)	5575 (215)	390 (57)
All pneumonia hospitalizations	51,335 (1051)	33,690 (608)	135,685 (2062)	550,020 (5835)	110,185 (2035)	19,585 (476)	500 (68)
Aged ≥ 65 years							
Pneumonia in first DF	20,115 (417)	10,770 (291)	152,060 (1886)	227,090 (2559)	97,270 (1489)	2205 (110)	420 (55)
Pneumonia in second DF	36,625 (694)	16,360 (388)	183,265 (2593)	181,905 (2747)	107,015 (1799)	1770 (101)	405 (65)
Pneumonia in any other DF	74,655 (1180)	17,190 (506)	178,365 (2611)	87,135 (1717)	74,070 (1513)	1270 (88)	935 (104)
All pneumonia hospitalizations	131,395 (1821)	44,320 (855)	513,690 (5759)	496,130 (5565)	278,355 (3844)	5245 (183)	1760 (172)

DF, diagnosis field; SE, standard error; SNF, skilled nursing facility.

including 46.6%, 71.9%, and 93.2% of younger patients and 56.3%, 80.9%, and 94.7% of older patients with pneumonia in the first, second, and any other DFs, respectively (Table 3). Likewise, the percentage classified as having a major to extreme likelihood of dying upon discharge also increased with pneumonia discharge position in both younger and older adults.

Alternative Criteria for Identifying Pneumonia-Associated Hospitalizations

Compared with the criteria used by Griffin and colleagues,¹ our study criteria identified 81% more pneumonia-associated hospitalizations in adults 18 years and older (ie, 2.37 million vs 1.31 million hospitalizations) (eAppendix Table 5).

DISCUSSION

We found that although 90% of pneumonia hospitalizations were identified in the first 6 DFs, just one-third were in the first DF. Consequently, claims-based estimates focusing only on the first DF underestimate pneumonia hospitalization burden. Excluding

patients with nonprimary pneumonia coded positions from studies using administrative claims may also exclude many of the most severe pneumonia hospitalizations, as secondary diagnoses were associated with higher LOS, costs, and CFRs and sicker patients overall compared with primary diagnoses.

The overall incidence of pneumonia hospitalization in younger adults (453/100,000) in the current analysis was higher than IRs previously reported when examining pneumonia only as a primary discharge diagnosis or when included with septicemia or respiratory failure (septicemia, meningitis, empyema in the study by Griffin and colleagues) as the primary diagnosis (80-370/100,000).^{1,2,5} The IR among older adults (3185/100,000) was also higher than reported rates using a more limited case definition (~850-1400/100,000).^{2,4} Using clinical and radiographic data instead of discharge codes for all hospitalized adult residents in Louisville, Kentucky, a prospective population-based cohort study estimated annual incidences of community-acquired pneumonia (CAP) closer to those reported here (327/100,000 and 2093/100,000 for adults aged 18-64 and ≥ 65 years, respectively).¹⁵ This study extrapolated data to the US population to estimate 1.7

TABLE 3. Illness Severity and Likelihood of Dying Among Patients With Pneumonia Hospitalizations by Discharge DF*

Study population	Severity of illness		Likelihood of dying	
	Minor to moderate, %	Major to extreme, %	Minor to moderate, %	Major to extreme, %
Aged 18-64 years				
Pneumonia in first DF	53.4	46.6	71.1	28.9
Pneumonia in second DF	28.1	71.9	53.2	46.7
Pneumonia in any other DF	6.7	93.2	15.5	84.5
Aged ≥ 65 years				
Pneumonia in first DF	43.7	56.3	50.9	49.1
Pneumonia in second DF	19.1	80.9	15.1	84.8
Pneumonia in any other DF	5.3	94.7	4.4	95.6

DF, diagnosis field.

*The data are based on All Patient Refined Diagnosis Related Groups. The severity of illness and likelihood of dying categories are from 3M.

million annual CAP hospitalizations or 1.5 million unique CAP hospitalizations (ie, excluding rehospitalizations).

Mean LOS per pneumonia hospitalization was similar to LOS reported in a previous study³ and was higher among younger vs older adults (8.4 vs 7.3 days). The difference in overall mean LOS between younger and older adults was primarily driven by shorter LOS for older vs younger adults associated with pneumonia in the third or higher DF. This result may have occurred because of a higher mortality rate among older adults (thus shortening their hospital stay), because older adults were more likely than younger adults to be transferred to a different acute or subacute care facility to complete their care, or because health care professionals more readily hospitalized older adults with less severe presentations.

Compared with previous studies, the primary economic impact of including pneumonias in additional DFs derived from increasing the total number of included fields rather than increasing the cost per episode. For example, previous studies that included pneumonia only in the first DF or combined pneumonia with primary septicemia or respiratory failure found direct medical costs for pneumonia of \$22,354 per episode among persons aged 18 to 64 years³ and \$16,689 to \$18,942 (cost/episode)³ or \$13,825 (in-hospital cost)⁴ among those 65 years or older. Similarly, our study found mean direct medical costs of \$24,637 for younger adults and \$18,360 for older adults. Decreased costs associated with older vs younger adults may have been due to the shorter mean LOS in the older population.

Additionally, compared with an earlier study, the impact of our study for pneumonia mortality burden was primarily related to the increase in pneumonias identified rather than differences in pneumonia CFR. We found an in-hospital CFR associated with any pneumonia diagnosis of 8.9% in older adults, within the 7.0% to 11.5% range for those 65 years and older reported previously.¹ For younger adults, we found an in-hospital CFR of 5.7%, higher than the 2.2% to 4.9% range for ages 18 to 64 years reported previously.¹

Both our study and earlier studies may underestimate the long-term impact of pneumonia on early mortality. For example, a study of US Medicare beneficiaries 65 years or older reported a 1-year 16.3% CFR difference for patients with pneumonia (30.8%) compared with otherwise similar patients without pneumonia (14.5%).¹⁶

Our strategy to identify pneumonia-associated hospitalizations was more sensitive than that of another study that relied on administrative data.¹⁷ Similarly, our approach was more sensitive than those of other studies that limited hospitalizations to only those with pneumonia coded in the primary DF or additionally included only a limited number of alternative primary diagnoses (eg, septicemia or respiratory failure) combined with pneumonia coded in any other discharge DF.¹⁻⁶ These studies attempted to focus

on what they considered to be the most likely hospitalizations for CAP instead of all pneumonia-associated hospitalizations.

In estimating pneumonia burden, some researchers have limited the case definition to CAP by excluding individuals who within 14 days preceding the pneumonia hospitalization were discharged from a long-term care facility, had a previous hospitalization, or required mechanical ventilation, as these patients may have had hospital-acquired pneumonia (HAP), VAP, or aspiration pneumonia.^{3,4} The ICD-9-CM classification system does not include specific codes for HAP, so we were unable to evaluate its prevalence among hospitalizations in our study, but very small percentages of pneumonia hospitalizations were associated with VAP or aspiration pneumonia. Moreover, distinguishing between CAP and these additional categories may be less relevant when considering public health interventions to combat pneumonia. Some strategies may be setting-specific, whereas others (eg, vaccination) may affect any setting. Future research is needed to define the etiologic agents of HAP and VAP because these categories might contribute to overall burden and are more likely to result in severe outcomes, such as intensive care unit admission. Furthermore, although VAP is relatively uncommon, HAP constitutes a substantial proportion of all pneumonia cases, with a 2010 cross-sectional 1-day survey of a sample of US hospitals projecting 186,000 HAP cases annually.¹⁸ An administrative database analysis of all pneumonia-associated hospitalizations (ie, any discharge diagnosis) among New York City residents 18 years or older from 2010 to 2014 found that 54.3% were CAP, 30.2% were health care-associated pneumonia (no longer a guideline-recommended definition¹⁹; also community acquired), and 14.0% and 1.6% were HAP and VAP, respectively.²⁰

Reasons for placing pneumonia in different DFs are unclear; however, our data suggest a possible answer. When pneumonia was coded in the first DF in our study, patients were less likely to have severe complications from either the pneumonia itself or an

underlying comorbid condition, and patients were more likely to have an APR-DRG of simple pneumonia. This is logical because pneumonia generally involves straightforward treatment, so regardless of whether pneumonia was the original reason for hospitalization, health care providers are likely to spend more time managing an underlying comorbid condition than the pneumonia itself.

Our results argue against the methodology of estimating the pneumonia burden by excluding pneumonias coded outside the first discharge DF (or associated with sepsis or respiratory failure). Pneumonias occurring in the second or higher DF because of underlying comorbidities were associated with the most severe pneumonia hospitalizations, and therefore excluding these cases from burden estimates will potentially omit the subset of pneumonias that are most relevant and critical to prevent.

Our study did not assess the performance of the *ICD-9-CM* classification for pneumonia hospitalizations. Although some studies report that sensitivity may be suboptimal,^{21,22} the *ICD-9-CM* classification has shown high positive predictive value (PPV) (88%) when using a single DF to identify pneumonia, even in ambulatory settings.²³ Notably, in a study evaluating children younger than 19 years hospitalized with CAP, which used *ICD-9-CM* codes similar to those used in our study, expanding the discharge DFs to identify pneumonia from the first to any discharge field increased sensitivity from 71.0% to 99.7% but reduced specificity from 90.9% to 75.7% and reduced PPV from 80.1% to 67.9%¹⁷; the trade-offs among sensitivity, specificity, and other performance characteristics warrant further research. We can examine how performance characteristics could affect our estimates if we assume that the above PPVs reported in children are valid for adults in our study (and that pneumonia hospitalizations in adults have high negative predictive value). In this case, we applied PPVs of 80.1% and 67.9%, for hospitalizations and costs for pneumonia in the first or in any DF, respectively, to our 2014 estimates. Our estimates of 808,165 and 2,373,030 pneumonia hospitalizations in the first and in any DF, and corresponding associated medical costs of \$8.8 billion and \$48.4 billion, respectively, would result in 647,340 and 1,611,287 pneumonia hospitalizations in the first and in any DF, and in \$7.1 billion and \$32.8 billion in corresponding associated medical costs, respectively. As this example shows, even after adjusting for PPVs, including pneumonia in any DF increases the accuracy of assessing hospital pneumonia burden and cost compared with using pneumonia only in the first DF. Specifically, for our study, PPV-adjusted pneumonia hospitalizations and associated costs of pneumonia in any DFs were 2.0 and 3.7 times, respectively, higher than the unadjusted estimates based on pneumonia diagnosis only in the first DF.

Our study was based on hospitalizations in 2014, the final entire year using the *ICD-9-CM* classification system. The 2015 year was a transition year, with the last quarter introducing the *ICD-10-CM* classification. NIS data for subsequent years were not available at the time of this study. To guide future studies under the *ICD-10-CM* classification, as a starting point, the *ICD-10-CM*

codes used in a study in Finland to identify pneumonia-related hospitalizations were J10.0, J11.0, J12-J18, J85.1, and J86.²⁴ The use of specific *ICD-10-CM* codes for pneumonia will likely become an important area of research in the near future.

Data regarding LOS, total hospital days, mortality rates, discharge disposition, and direct medical costs in our study cannot be attributed to pneumonia specifically because most patients with pneumonia hospitalizations had additional diagnoses that likely contributed to these outcomes. The degree to which outcomes were affected by pneumonia may vary considerably. For example, chronic obstructive pulmonary disease or congestive heart failure may have been precipitated by a pneumonia episode, in which case pneumonia would be the primary driver of associated outcomes. Alternatively, pneumonia may have been an incidental and relatively trivial component of hospitalization. These distinctions can potentially be explored in more robust analyses, including chart review or a control population; one example is a claims-based study of Medicare beneficiaries 65 years and older, in which the incremental direct medical cost of pneumonia during 1 year of follow-up was \$15,682 (~\$22,500 in 2018 US\$) higher for patients with pneumonia in the first DF than for matched control patients without pneumonia.¹⁶ However, regardless of whether pneumonia is the cause of the outcomes measured here, the outcomes are nevertheless an accurate reflection of pneumonia hospitalizations complicated by multiple diagnoses regardless of whether pneumonia is included in the first discharge DF.

Our data demonstrate that hospitalizations associated with pneumonia in any discharge DF can have enormous financial consequences. The total cost of adult hospitalizations with pneumonia (primarily simple pneumonia) reported in the first discharge DF in 2014 was \$8.8 billion, similar to costs reported for 2013 in an HCUP analysis (\$9.5 billion for all ages).²⁵ When we included hospitalizations with any pneumonia diagnosis, estimated 2014 costs were \$48.3 billion, representing more than 12% of all US hospitalization costs in 2013.²⁵ Although many of these costs would likely have accrued without the pneumonia, it is likely that a substantial proportion of the economic burden could have been avoided if pneumonia were prevented. Furthermore, during the COVID-19 pandemic, access to routine immunization has experienced major challenges.²⁶ Actions to improve delays in routine vaccination may free up scarce health care resources, including hospital and intensive care unit beds and mechanical ventilation, during the COVID-19 pandemic.²⁷

Limitations

Our study did not attempt to disentangle what part of the total cost of a pneumonia-associated hospitalization was due to pneumonia or due to other underlying conditions that may have triggered or further complicated the hospitalization. This is difficult to assess. Some methodologies, such as recycled predictions, have been used in attempts to separate the potential incremental cost of a diagnosis in the context of multiple diagnoses that were part of a

hospital discharge.²⁸ Nevertheless, although we did not estimate the extent of the role of pneumonia in the cost of a pneumonia-related hospitalization, avoiding a hospitalization for pneumonia or avoiding a pneumonia episode in the course of a hospitalization would have prevented or reduced the medical cost associated with the hospitalization.

CONCLUSIONS

Pneumonia hospitalization burden reflected in administrative claims data for hospital discharges depends largely on inclusion criteria. In our analysis, IRs and human and economic burdens when including pneumonias coded in any DF were markedly higher than rates based only on primary pneumonia diagnoses. For an acute condition such as pneumonia, we propose that IR estimates should include all appropriate hospitalizations regardless of the discharge DF in which pneumonia is coded. We are unaware of any scientific rationale for including only pneumonias coded in the first discharge DF.

Additionally, because illness severity and hospitalization were lower in patients hospitalized with pneumonia in the first discharge DF than in other positions, focusing solely on this group underestimates pneumonia burden. We have demonstrated that hospitalizations with pneumonia coded in the second or higher DFs were associated with tremendous health care utilization and direct medical costs, in fact accounting for the majority of all costs attributed to pneumonia hospitalizations. The extent to which pneumonia contributed to the reported outcomes, as well as the extent to which the reported outcomes could have been mitigated by preventive intervention (eg, vaccination against influenza or pneumococcal disease), should be investigated in future studies. Similar to estimated IR, these studies should evaluate the contribution of pneumonia to economic burden regardless of the discharge DF. ■

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eAppendix Material

National Inpatient Sample

The National Inpatient Sample (NIS) is part of the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality (AHRQ) and provides a population-weighted, 20% sample of all annual discharges in US community hospitals.^{9,10} The NIS analysis unit is a hospitalization; each NIS hospital discharge includes data on patient demographics, flags for selected comorbidities, clinical and procedure diagnosis codes, LOS, total charges, and cost-to-charge ratios. The HCUP additionally provides information on charges for each hospitalization and cost-to-charge ratios.¹¹

Ethics Statement

To protect individual and institutional privacy within HCUP data sets, this study strictly adhered to the HCUP Data Use Agreement with the Healthcare Cost and Utilization Project Agency for Healthcare Research and Quality. No attempts were made to identify patients, physicians, or healthcare providers.

Most Frequently Used ICD-9-CM Codes

The most frequently used ICD-9-CM codes among patients in both age groups were 482, 486, and 487.0 in the first discharge diagnosis position, and 482 and 486 in the second and any discharge diagnosis positions.

eAppendix Table 1. Top 10 Hospital Discharge Diagnosis Codes in the First Discharge Diagnosis Field Among Hospitalizations With Pneumonia in the Second or Other Discharge Diagnosis Field

First Discharge Diagnosis	ICD-9-CM Code	Pneumonia in Second Diagnosis Field (n=828,645)		Pneumonia in Any Other Diagnosis Field (n=736,220)	
		Rank	%	Rank	%
Nonspecific septicemia	0389	1	24.2	1	28.2
Obstructive chronic bronchitis with acute exacerbation	49121	2	8.3	3	2.9
Respiratory failure	51881	3	3.7	2	4.1
Acute and chronic respiratory failure	51884	4	2.8	4	2.6
Acute or chronic diastolic heart failure	42833	5	2.6	6	2.0
Pneumonitis due to inhalation of food or vomitus	5070	NA	NA	7	1.9
Acute or chronic systolic heart failure	42833	6	2.4	8	1.7
Nonspecific acute renal failure	5849	7	1.8	10	1.3
Initial subendocardial infarction	41071	8	1.8	5	2.3
Congestive heart failure	4280	9	1.7	NA	NA
Chronic obstructive asthma with acute exacerbation	49322	10	1.7	NA	NA
Care involving other specified rehabilitation procedure	V5789	NA	NA	9	1.4

ICD-9-CM=International Classification of Diseases, 9th Revision, Clinical Modification;
NA=not applicable (not included within the top 10 codes ranked within the column).

eAppendix Table 2. Most Common Non-Pneumonia Diagnosis Codes Among Pneumonia Hospitalizations by Discharge Diagnosis Field^a

First Discharge Diagnosis	ICD-9-CM Code	Pneumonia in Any Diagnosis Field, % (n=2,373,030)	Pneumonia in First Diagnosis Field, % (n=808,165)	Pneumonia in Second Diagnosis Field, % (n=828,645)	Pneumonia in Any Other Diagnosis Field, % (n=736,220)
Respiratory failure	51881	19.2	12.2	14.1	32.6
Nonspecific septicemia	0389	18.3	0.7	24.2	30.9
Nonspecific acute renal failure	5849	14.2	11.1	16.7	14.6
Obstructive chronic bronchitis with acute exacerbation	49121	12.2	13.2	16.0	6.9
Nonspecific hypertension	4019	9.1	15.1	7.9	3.8
Acute and chronic respiratory failure	51884	7.5	6.5	6.2	10.0
Congestive heart failure	4280	7.5	8.0	9.2	4.9
Hyposmolality	2761	6.2	8.2	6.8	3.2
Atrial fibrillation	42731	6.1	7.0	7.6	3.3
Nonspecific urinary tract infection	5990	5.8	6.1	7.3	3.8
Uncomplicated type II diabetes	25000	4.9	7.4	4.9	2.0
Septic shock	78552	4.4	0.3	2.2	11.4

Hyperlipidemia NEC/NOS	2724	3.8	6.1	2.5	2.6
Nonspecific pleural effusion	5119	3.7	3.2	5.1	2.8
Chronic airway obstruction NEC	496	3.6	5.6	3.6	1.5
Systemic inflammation/infection without organ dysfunction	99591	3.6	0.7	6.6	3.5
Initial subendocardial infarction	41071	3.1	0.9	2.8	5.8
Acidosis	2762	2.3	1.2	2.9	2.9
Acute or chronic diastolic heart failure	42833	2.5	1.4	2.6	3.7
Tobacco use disorder	3051	2.3	3.4	2.3	1.1
Nonspecific bacterial pneumonia	4829	2.2	3.5	2.7	0.0
End stage renal disease	5856	1.8	2.8	0.0	2.8
Acute or chronic systolic heart failure	42823	1.4	0.0	2.4	1.6
Influenza with pneumonia	4870	1.1	3.3	0.0	0.0
Atherosclerosis of a native coronary artery	41401	1.0	1.5	1.0	0.6
Esophageal reflux	53081	1.0	1.7	0.8	0.4
Nonspecific anemia	2859	0.9	1.2	1.0	0.5
Care involving other specified rehabilitation procedure	V5789	0.9	0.0	1.3	1.4

Lower nephron nephrosis	5845	0.9	0.2	0.7	1.8
Metabolic encephalopathy	34831	0.8	1.0	0.0	1.5
Other gram negative pneumonia	48283	0.8	2.4	0.0	0.0

ICD-9-CM=International Classification of Diseases, 9th Revision, Clinical Modification; NEC=not elsewhere classified; NOS=not otherwise classified.

^aMost common diagnosis codes were ICD-9 codes appearing in any of the first 5 hospital discharge diagnosis fields and that combined accounted for $\geq 1\%$ of associated pneumonia hospitalizations.

eAppendix Table 3. Most Common Diagnosis-Related Groups Among Pneumonia Hospitalizations by Discharge Diagnosis Field

APR-DRG	APR-DRG Number	Pneumonia in Any Diagnosis Field (n=2,373,030)		Pneumonia in First Diagnosis Field (n=808,165)			Pneumonia in Second Diagnosis Field (n=828,645)			Pneumonia in Any Other Diagnosis Field (n=736,220)		
		N	% of All Pneumonias	N	% of First DF Pneumonias	% of APR-DRG	N	% of Second DF Pneumonias	% of APR-DRG	N	% of Other DF Pneumonias	% of APR-DRG
Septicemia or severe sepsis without MV \geq 96 hours with MCC	871	406,755	17.1	0	0.0	0.0	217,700	26.3	53.5	189,055	25.7	46.5
Simple pneumonia and pleurisy with CC	194	319,365	13.5	318,610	39.4	99.8	105	0.0	0.0	650	0.1	0.2
Simple pneumonia and pleurisy with MCC	193	243,385	10.3	242,190	30.0	99.5	285	0.0	0.1	910	0.1	0.4
Simple pneumonia & pleurisy without CC/MCC	195	147,830	6.2	147,420	18.2	99.7	310	0.0	0.2	100	0.0	0.1
Chronic obstructive pulmonary disease with MCC	190	116,050	4.9	0	0.0	0.0	90,850	11.0	78.3	25,200	3.4	21.7
Heart failure and shock with MCC	291	115,375	4.9	0	0.0	0.0	72,445	8.7	62.8	42,930	5.8	37.2

Respiratory system diagnosis with ventilator support <96 hours	208	49,295	2.1	13,620	1.7	27.6	13,975	1.7	28.4	21,700	3.0	44.0
Pulmonary edema and respiratory failure	189	49,140	2.1	0	0.0	0.0	31,235	3.8	63.6	17,905	2.4	36.4
Septicemia or severe sepsis with MV ≥96 hours	870	44,025	1.9	0	0.0	0.0	5805	0.7	13.2	38,220	5.2	86.8
Respiratory infections and inflammations with MCC	177	42,295	1.8	28,800	3.6	68.1	4075	0.5	9.6	9420	1.3	22.3
Infectious and parasitic diseases with OR procedure with MCC	853	34,500	1.5	0	0.0	0.0	11,335	1.4	32.9	23,165	3.2	67.1
Respiratory system diagnosis with ventilator support ≥96 hours	207	32,420	1.4	9290	1.2	28.7	7655	0.9	23.6	15,475	2.1	47.7
Renal failure with MCC	682	29,480	1.2	0	0.0	0.0	17,275	2.1	58.6	12,205	1.7	41.4
Acute myocardial infarction, discharged alive with MCC	280	26,220	1.1	0	0.0	0.0	13,295	1.6	50.7	12,925	1.8	49.3
Respiratory infections and inflammations with CC	178	24,485	1.0	19,625	2.4	80.2	270	0.0	1.1	4590	0.6	18.8

APR-DRG=All Patient Refined Diagnosis Related Group; CC=complicating or comorbid condition; DF=diagnosis field; MCC=major complicating or comorbid condition; MV=mechanical ventilation; OR=operating room

eAppendix Table 4. Prevalence of Selected Conditions and Corresponding ICD-9 Codes Among All Pneumonia Hospitalizations

Condition	ICD-9-CM Code	Pneumonia in Any Diagnosis Field (n=2,373,030)		Pneumonia in First Diagnosis Field (n=808,165)			Pneumonia in Second Diagnosis Field (n=828,645)			Pneumonia in Any Other Diagnosis Field (n=736,220)		
		N	% of All Pneumonias	N	% of First DF Pneumonias	% of Condition	N	% of Second DF Pneumonias	% of Condition	N	% of Other DF Pneumonias	% of Condition
Ventilator-associated pneumonia	99731	4740	0.2	215	0.0	4.5	575	0.1	12.1	3950	0.5	83.3
Pneumonitis due to inhalation of food or vomitus	5070	28,570	1.2	1500	0.2	5.3	3920	0.5	13.7	23,150	3.1	81.0

DF=diagnosis field; ICD-9-CM=International Classification of Diseases, 9th Revision, Clinical Modification.

eAppendix Table 5. Comparison of Criteria Used by Griffin et al.* and Suaya et al. (This Study) to Identify Hospitalizations with Pneumonia based on ICD-9 Codes in Discharge Diagnosis Fields

Diagnosis	Griffin et al. Criteria			Suaya et al. Criteria		
	Age 18–64 years	Age ≥65 years	Total in age ≥18 years	Age 18–64 years	Age ≥65 years	Total in age ≥18 years
Pneumonia in first discharge diagnosis field	297,975	510,190	808,165	297,975	510,190	808,165
Septicemia in first diagnosis and pneumonia in any other discharge diagnosis field	192,480	307,920	500,400	n.a.	n.a.	n.a.
Empyema in first diagnosis and pneumonia in any other discharge diagnosis field	3490	1850	5340	n.a.	n.a.	n.a.
Meningitis in first diagnosis and pneumonia in any other discharge diagnosis field	440	200	640	n.a.	n.a.	n.a.
Pneumonia in second discharge diagnosis field	n.a.	n.a.	n.a.	301,100	527,545	828,645
Pneumonia in any other discharge diagnosis field	n.a.	n.a.	n.a.	302,395	433,825	736,220
Total pneumonia hospitalizations	494,385	820,160	1,314,545	901,470	1,471,560	2,373,030

* Griffin et al. *N Engl J Med.* 2013;369(2):155-163.

n.a.=not applicable.